NASA/TP—2004–213281

Application of the Maximum Amplitude-Early Rise Correlation to Cycle 23

Robert M. Wilson and David H. Hathaway
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June 2004

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NOMENCLATURE

a	y-axis intercept
b	slope
EM	epoch of maximum amplitude
P	probability
R	amplitude
RM	maximum amplitude
Rm	minimum amplitude
$R(t)$	smoothed monthly mean sunspot number at elapsed time t from sunspot minimum
r	linear correlation coefficient
r^2	determination coefficient
se	standard error of estimate
$\mathrm{Slope}_{\mathrm{ASC}}$	average slope during a cycle’s ascent
t	elapsed time
t_b	t-statistic for evaluating the statistical significance of the inferred relationship between RM and $R(t)$

TECHNICAL PUBLICATION

APPLICATION OF THE MAXIMUM AMPLITUDE-EARLY RISE CORRELATION TO CYCLE 23

1. INTRODUCTION

Prior to the start of cycle 23—the present ongoing sunspot cycle—and during its early rise, much speculation was given that it potentially would be a fast-rising sunspot cycle of large maximum amplitude,[1–5] the basis for such speculation being readily available precursor information. However, now that maximum amplitude for cycle 23 has clearly been achieved, the Sun has demonstrated once again that its behavior sometimes does not follow expectations.[6–7]

In this Technical Publication, examination of simple methodologies and techniques applicable for the prediction of cycle maximum of an ongoing sunspot cycle is continued. Recently, the relationship between maximum amplitude and the observed maximum daily value of sunspot number, the maximum monthly mean value of sunspot number, and the maximum value of the 2-mo moving average of monthly mean sunspot number were examined.[7] In particular, those parameters were found to be especially useful for monitoring the expected size and timing of an ongoing sunspot cycle, and together they predicted that cycle 23 would have a maximum amplitude of ≈124.5 near July 2000 ±5 mo. Here, the rising portion of cycle 23 from conventional onset in May 1996 through 50 mo past cycle minimum is examined using the maximum amplitude-early rise correlation[8] (the correlative behavior found to exist between the later occurring maximum amplitude of the cycle and its current value of smoothed monthly mean sunspot number at various times throughout its rise). The 90-percent prediction envelope for cycle 23's expected maximum amplitude is determined, and it is shown that, as early as 12 mo into the cycle, the expected maximum amplitude for cycle 23 probably would not differ appreciably from that of the mean cycle. Furthermore, as early as 18 mo into cycle 23, its behavior was such that it was highly unlikely that it would have a maximum amplitude as great or greater than ≈160, a value (±30) that had been predicted for it on the basis of precursor information.[3]

As it turned out, cycle 23 attained a maximum amplitude of 120.8 (in terms of smoothed monthly mean sunspot number), a value slightly larger than that of the mean sunspot cycle, peaking in April 2000 or 47 mo past its May 1996 conventional cycle minimum. Also, now that its primary maximum has clearly been determined (with a smaller secondary peak occurring later in 2001), the occurrence of conventional sunspot minimum for the next sunspot cycle—cycle 24—can be anticipated. Statistically speaking, cycle 23 appears very likely to be a cycle of shorter period,[9,10] having a conventional cycle length (minimum-to-minimum period) ≤126 mo. (The observed range during the modern era for shorter period cycles is 116–126 mo.) If true, then conventional minimum for cycle 24 should occur before December 2006, probably near July 2006. If, however, cycle 23 proves to be a statistical outlier, then it would be a cycle of longer period, having a period equal to or longer than 135 mo (the observed range during the modern era for longer period cycles is 135–142 mo) and conventional minimum for cycle 24 would not occur until after July 2007, probably near December 2007.

2. RESULTS AND DISCUSSION

Previously, it was shown that the maximum amplitude of a progressing sunspot cycle is directly correlated against the observed current size of smoothed monthly mean sunspot number (the 12-mo moving average or 13-mo running mean) during its rise from conventional cycle minimum to maximum, in particular, after its first 12 mo of rise.[8] Thus, by monitoring the current size of the cycle, the later occurring conventional maximum amplitude can be estimated with increasing accuracy, especially as the cycle nears maximum amplitude.

Figures 1–4 display scatterplots of the maximum amplitude-early rise correlation at 3-mo intervals, from conventional sunspot minimum to 42 mo following conventional sunspot minimum. Subpanels (a)–(o) are similarly coded, identifying cycles of shorter period by filled triangles and cycles of longer period by filled circles. (This same coding is employed in figures 5–8 as well.) Also given in each subpanel is the 2×2 contingency table, determined by the median values (shown as the thin vertical and horizontal lines in each subpanel) of *RM* and *R*(*t*), where *RM* refers to the conventional maximum amplitude and *R*(*t*) is the smoothed monthly mean sunspot number at elapsed time (*t*) in months beyond conventional sunspot minimum and the probability (*P*) of obtaining the observed distribution or one more suggestive of a departure from independence on the basis of Fisher's exact test.[11] Likewise, the Pearson linear correlation coefficient (*r*), which when squared, yields the coefficient of determination that gives the fraction of variance explained by the inferred regression are also shown. When the confidence level of the correlation is inferred to be statistically significant (≥95 percent), the regression line is plotted as the thick diagonal line in subpanels (e)–(o). For convenience, the values of *R*(*t*) for cycle 23 are identified in each subpanel along the *x* axis using a small, downward-pointing arrow.

From figures 1–4, beginning ≈12 mo past conventional cycle minimum, the maximum amplitude-early rise correlation is found to be statistically important. At 18 mo past cycle minimum, the correlation is found to explain ≈60 percent of the variance in RM, and at 24 mo, it can explain slightly more than 70 percent of the variance.

During the first several months after cycle onset, values of smoothed monthly mean sunspot number for cycle 23 were to the right of the median, indicating that if this behavior persisted, then undoubtedly cycle 23 would be destined to have a maximum amplitude larger than the mean cycle and possibly one that could rival the largest of the modern era sunspot cycles, in agreement with early predictions based on precursor information.[1,3,5] However, as can be seen in figures 1–4, values of smoothed monthly mean sunspot number for cycle 23 dipped below the median and hovered near it for much of its rise, only becoming larger than the median once again just before the occurrence of maximum amplitude.

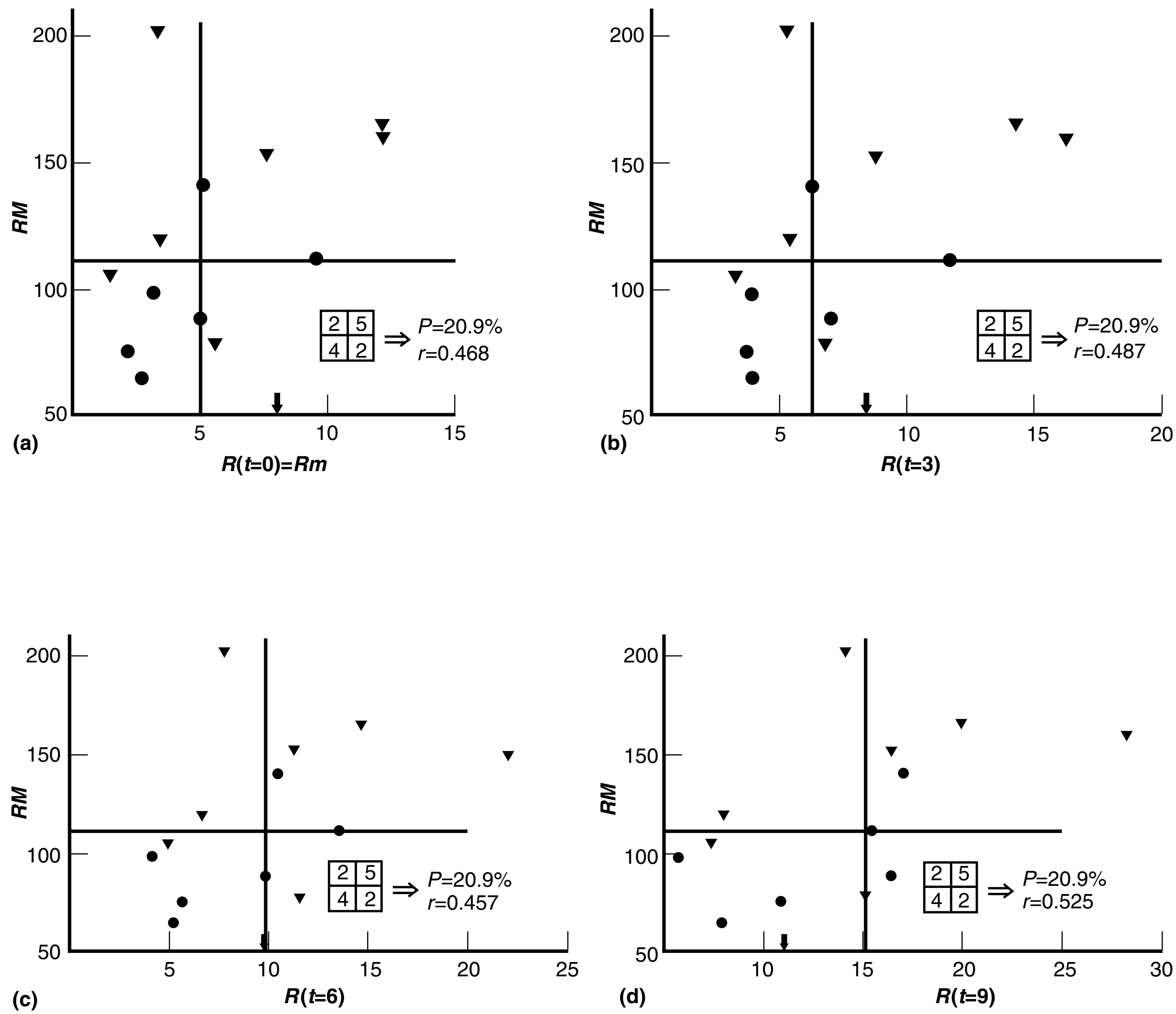

Figure 1. Maximum amplitude-early rise correlation plotted at 3-mo intervals in subpanels (a)–(d) for elapsed time from sunspot cycle minimum *t* equals 0 to 9 mo past minimum. See text for details.

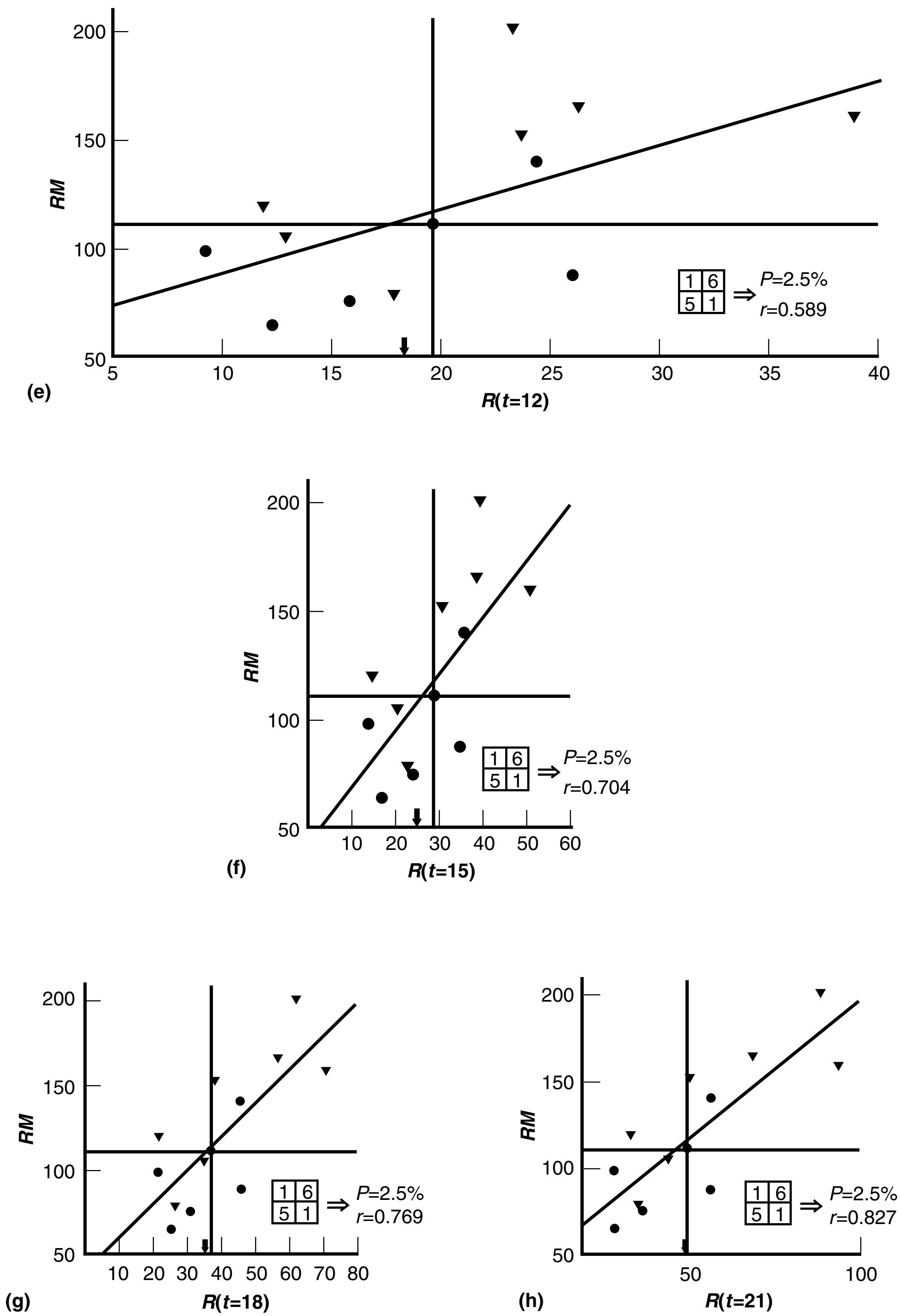

Figure 2. Maximum amplitude-early rise correlation plotted at 3-mo intervals in subpanels (e)–(h) for elapsed time *t* equals 12 to 21 mo past minimum. See text for details.

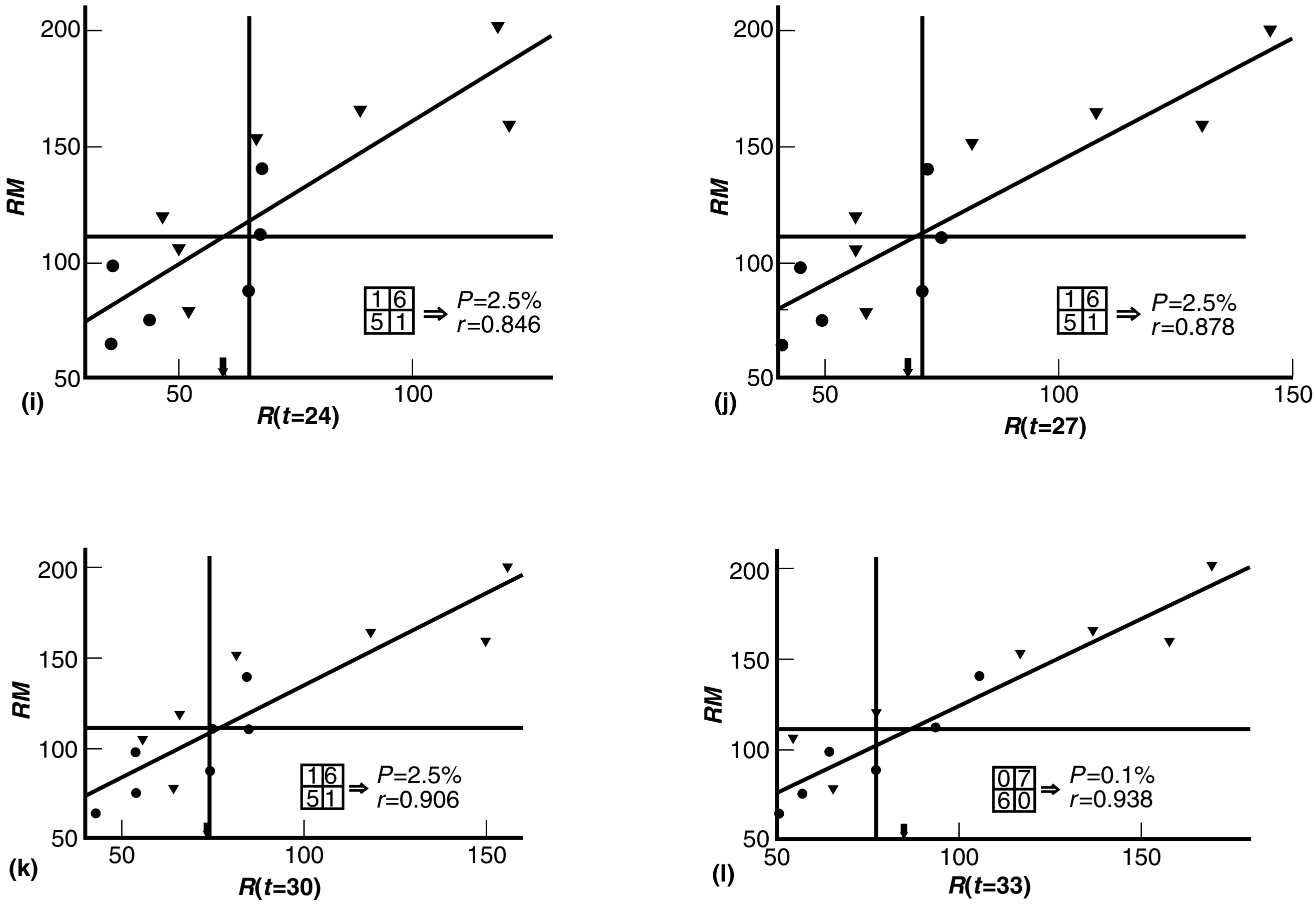

Figure 3. Maximum amplitude-early rise correlation plotted at 3-mo intervals in subpanels (i)–(l) for elapsed time *t* equals 24 to 33 mo past minimum. See text for details.

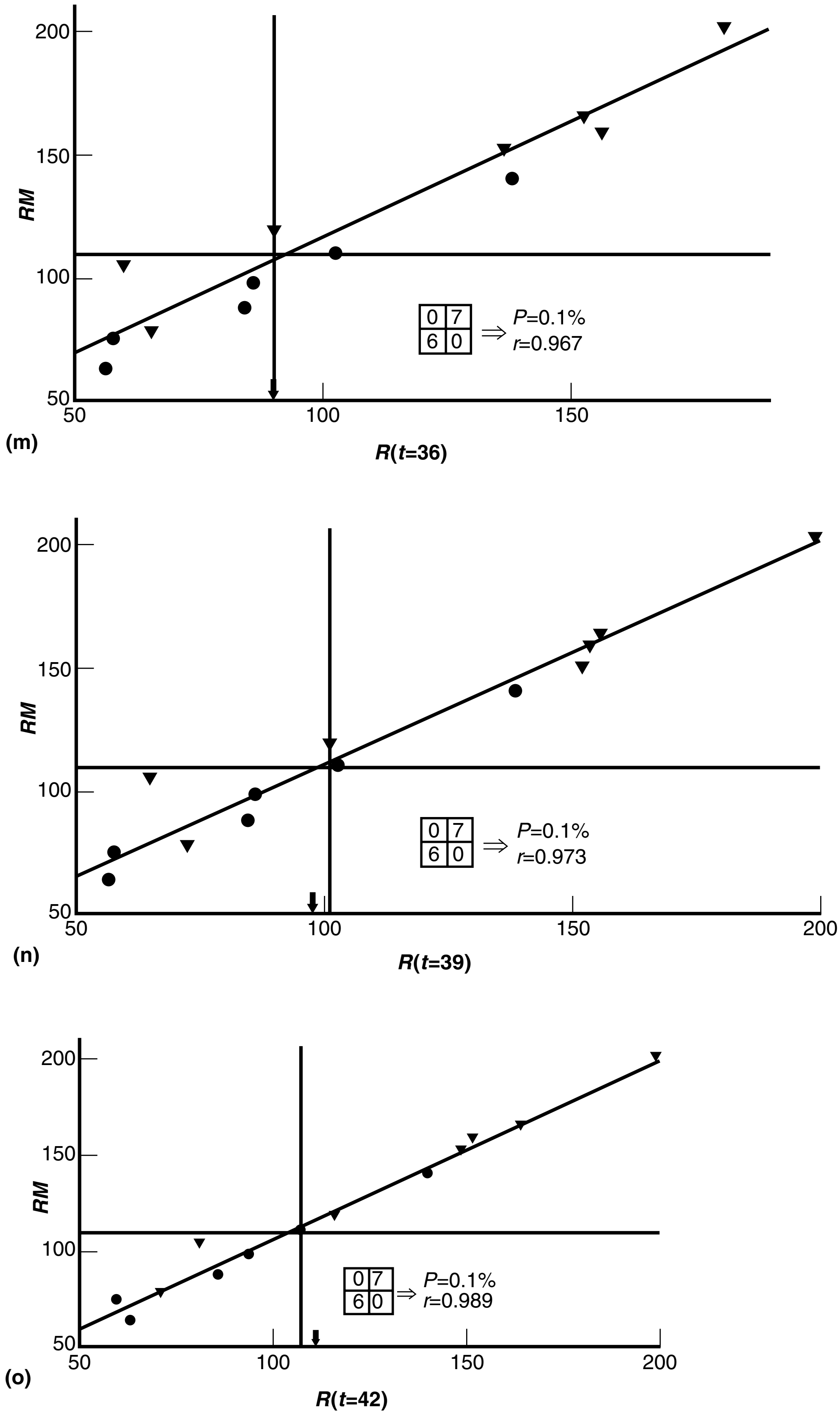

Figure 4. Maximum amplitude-early rise correlation plotted at 3-mo intervals in subpanels (m)–(o) for elapsed time *t* equals 36 to 42 mo past minimum. See text for details.

Figure 5 depicts the actual variation of smoothed monthly mean sunspot number during the first 50 mo of cycle 23, plotted as the dotted line traversing upward and to the right. Identified are minimum amplitude (Rm = 8 at t = 0), maximum amplitude (RM = 120.8 at t = 47 mo) and the $\text{Slope}_{\text{ASC}}$ (23), which equals 2.4, computed as the difference between maximum and minimum amplitudes divided by the ascent duration in months. Also shown is the 90-percent prediction envelope for RM as a function of t. At t = 12 mo, there was only a 5-percent chance that cycle 23 would have a maximum amplitude as large or larger than 176, and at t = 18 mo there was only a 5-percent chance that cycle 23 would have a maximum amplitude as large or larger than 159. In fact, throughout its rise, cycle 23 demonstrated that it likely would not meet its early expectations of being a cycle that would be appreciably larger than that of the mean cycle.

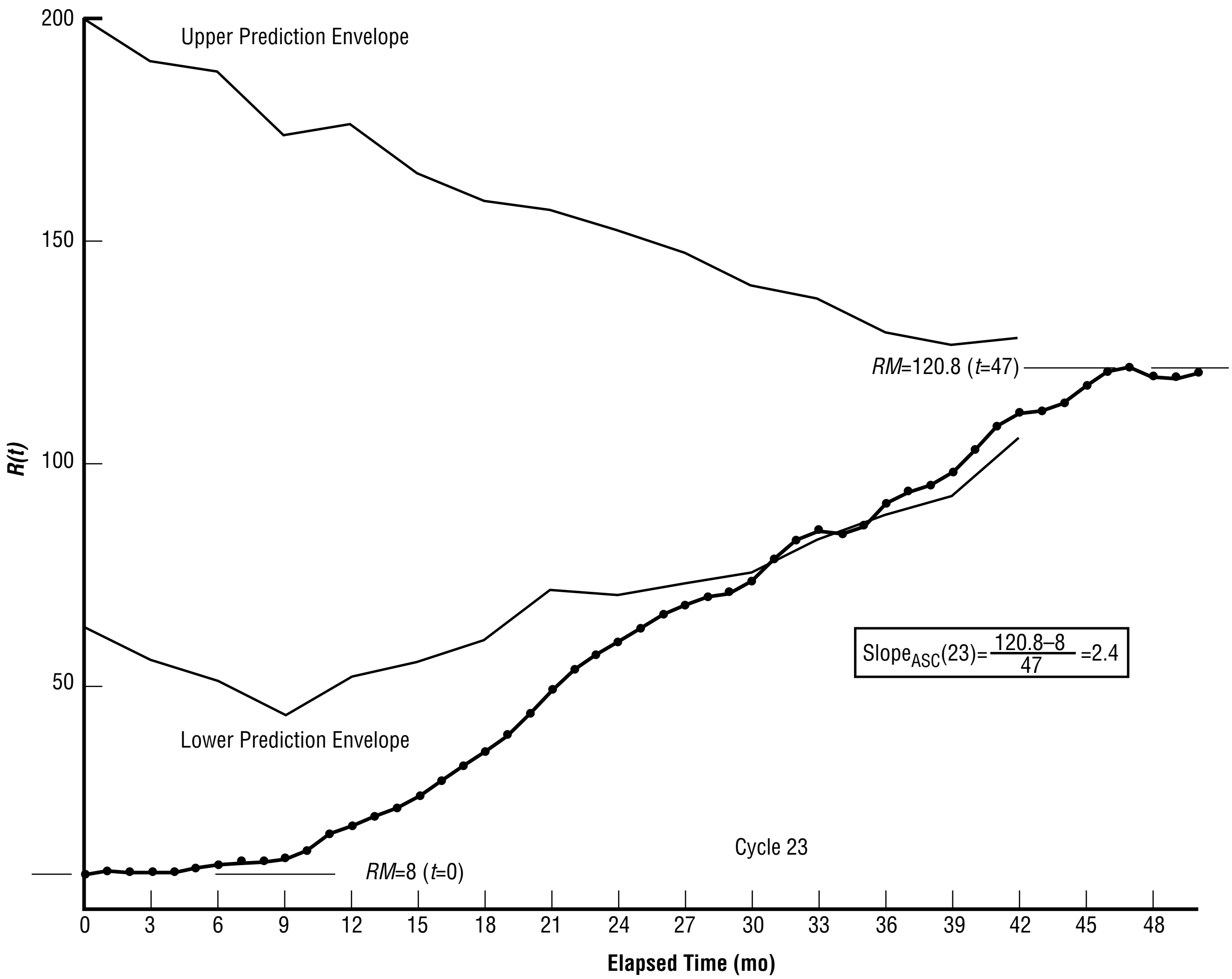

Figure 5. The growth of cycle 23 from cycle minimum t equals 0 to 50 mo past minimum. See text for details.

Figure 6 shows the scatterplot of descent duration (DES) in months versus ascent duration (ASC) in months, on the basis of conventional smoothed monthly mean sunspot number. Notice that individual sunspot cycles can be categorized separately on the basis of minimum-to-minimum period into two discernible groups: cycles of shorter period, averaging ≈122 mo in length and having a range of 116 to 126 mo, and cycles of longer period, averaging ≈139 mo in length and having a range of 135 to 142 mo. During the modern era of sunspot observations (cycles 10 to the present), no sunspot cycles have yet been seen having a conventional minimum-to-minimum period measuring 127 to 134 mo (also true for the earlier cycles 1–9, although these cycles are less reliably known). Thus, there is an apparent 8-mo "period gap" that bounds the length of the mean cycle when using conventional smoothed monthly mean sunspot numbers. Because cycle 23 had a conventional rise of 47 mo, its descent duration is anticipated to be either ≈75 ± 4 mo, if it is a cycle of shorter period, or ≈92 ± 4 mo, if cycle 23 is a cycle of longer period. Clearly, on the basis of ascent duration alone, it is impossible to differentiate the period class of an ongoing sunspot cycle.

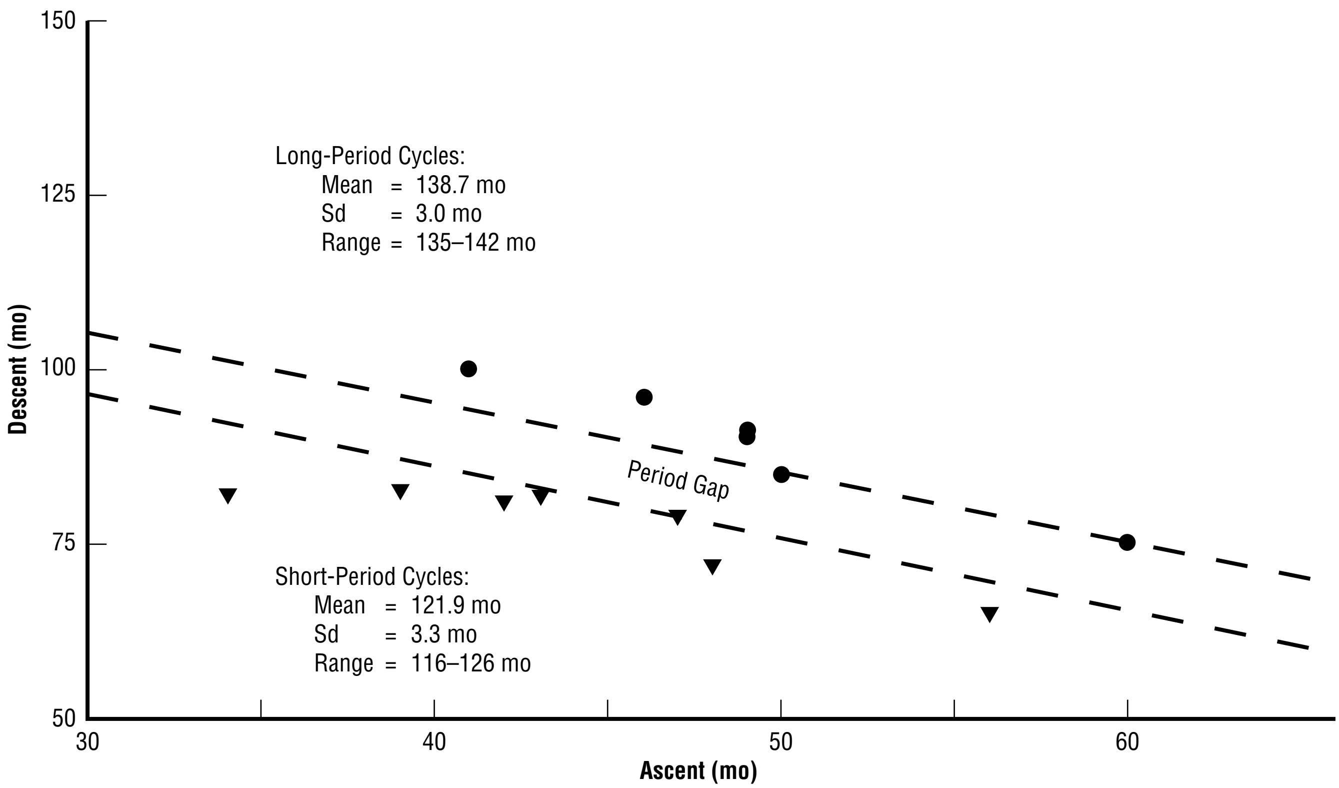

Figure 6. DES duration versus ASC duration for modern era sunspot cycles (10–22). See text for details.

Figure 7 displays the scatterplot of Period versus $Slope_{ASC}$, where Period is the cycle length expressed in months and $Slope_{ASC}$ is defined as before. Because of the apparent bifurcation of Period, a linear fit between the two parameters is not particularly strong, having only marginal statistical significance (a confidence level of 90 percent) and a correlation coefficient of –0.483. On the basis of the 2×2 contingency table, the probability (P) of obtaining the observed result, or one more suggestive of a departure from independence, is 7.8 percent, a marginally significant result (specifically caused by the 126-mo median for Period). However, using all known cycles, the median for Period becomes 130.5 mo (instead of 126 mo), the median of $Slope_{ASC}$ becomes 2.184 (instead of 2.165), and the 2×2 contingency table becomes 3:8:3:8 (instead of 1:5:2:5), thereby, inferring a probability (P) of 4.3 percent, which is a statistically significant result. Thus, because $SLOPE_{ASC}$ for cycle 23 equals 2.4, a value slightly larger than its median value, this seems to suggest that cycle 23 will be a cycle of shorter period. Hence, its descent duration will be <80 mo and conventional cycle minimum for cycle 24 should occur before December 2006.

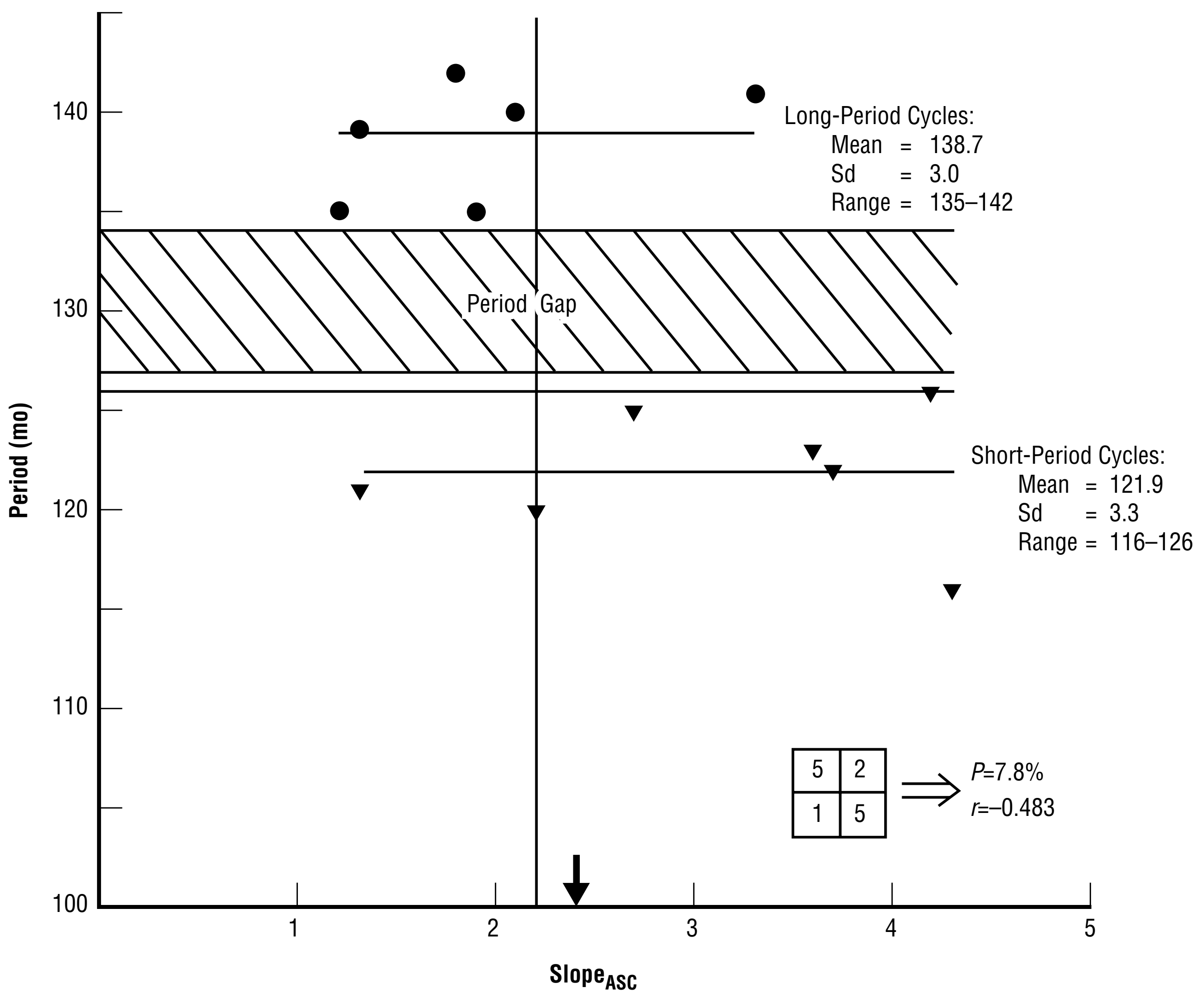

Figure 7. Period versus the average slope during a cycle's ascent ($Slope_{ASC}$). See text for details.

Recently, interesting relationships[12,13] were found to exist between the drift rate of the centroid of sunspot area towards the equator in each solar hemisphere and the length of the sunspot cycle. In particular, a highly significant anticorrelation was found between hemispheres having faster (slower) rates and shorter (longer) periods. Also, the drift rate at cycle maximum was found to be significantly correlated with the amplitude of the following cycles, especially the cycle two cycles removed. On the basis of these results, cycle 23 appears destined to be of shorter length and cycle 24 of larger than average size. (This is also consistent with the amplitude-period relationship,[14] where larger than average sized cycles tend to follow cycles of shorter than average length.)

Table 1 gives updated parametric values regarding the correlative relationships between *RM* and $R(t)$ values for the interval t equals 0 to 33 mo (the rising portion of a sunspot cycle). Identified are the linear correlation coefficients a and b from the linear equation $y = a + bx$, where y is *RM*, a is the y-axis intercept, b is the slope, and x is $R(t)$. Also identified are r, r^2, se, and t_b, corresponding, respectively, to Pearson's linear correlation coefficient, the coefficient of determination, the standard error of estimate, and the t-statistic for evaluating the statistical significance of the inferred relationship between *RM* and $R(t)$. The table should prove useful to those monitoring the rising portion of cycle 24, the next solar cycle, comparing ongoing maximum amplitude estimates to precursor predictions for its maximum amplitude. (For 14 cycles, there are 12 degrees of freedom, and a t_b value equal to 2.179 or more indicates a statistically significant result at the 95-percent confidence level; one equal to 3.055 or more indicates a very statistically significant result at the 99-percent confidence level.)

Table 1. Correlative relationships between RM and $R(t)$ for t equals 0 to 33 mo.

t	a	b	r	r^2	se	t_b
0	89.733	5.103	0.462	0.213	36.4	1.806
1	90.180	4.754	0.458	0.209	36.5	1.783
2	88.742	4.532	0.463	0.214	36.4	1.810
3	84.007	4.749	0.487	0.237	35.9	1.929
4	76.940	5.237	0.526	0.277	34.9	2.146
5	78.165	4.618	0.497	0.247	35.6	1.985
6	82.756	3.727	0.457	0.209	36.5	1.781
7	80.013	3.588	0.478	0.228	36.1	1.883
8	75.028	3.603	0.511	0.261	35.3	2.058
9	70.841	3.471	0.524	0.275	35.0	2.131
10	69.462	3.140	0.523	0.274	35.0	2.127
11	64.799	3.062	0.560	0.314	34.0	2.344
12	59.713	2.968	0.589	0.347	33.2	2.524
13	56.071	2.790	0.617	0.380	32.3	2.717
14	50.701	2.707	0.671	0.451	30.5	3.132
15	46.103	2.566	0.704	0.495	29.2	3.430
16	43.557	2.347	0.721	0.520	28.5	3.599
17	42.887	2.117	0.740	0.547	27.6	3.814
18	40.730	1.965	0.769	0.591	26.3	4.158
19	38.019	1.860	0.799	0.638	24.7	4.602
20	35.738	1.757	0.816	0.666	23.8	4.877
21	35.227	1.613	0.827	0.684	23.1	5.095
22	36.677	1.455	0.835	0.697	22.7	5.232
23	38.710	1.313	0.835	0.697	22.7	5.232
24	38.646	1.229	0.845	0.714	22.0	5.464
25	36.611	1.191	0.862	0.743	20.8	5.896
26	36.813	1.132	0.870	0.757	20.2	6.129
27	38.288	1.065	0.876	0.767	19.9	6.260
28	37.203	1.043	0.883	0.781	19.2	6.548
29	35.128	1.039	0.894	0.799	18.6	6.833
30	34.178	1.014	0.904	0.817	17.7	7.263
31	32.522	0.995	0.913	0.834	16.8	7.732
32	31.444	0.970	0.923	0.851	15.8	8.309
33	30.732	0.949	0.935	0.874	14.4	9.101

Legend:

t = elapsed time in months from Rm occurrence
a = y-intercept in the relationship $y=a+bx$
b = slope in the relationship $y=a+bx$
r = linear correlation coefficient
r^2 = coefficient of determination
se = standard error of estimate
t_b = t-statistic for evaluating the statistical significance of the inferred statistical relationship. For N=14 pairs, there are 12 degrees of freedom, and a value of $t \geq 1.782$ means the relationship is significant at the 90% level of confidence; a value of $t \geq 2.179$ means the relationship is significant at the 95% level of confidence; and a value of $t \geq 3.055$ means the relationship is significant at the 99% level of confidence.

Similarly, figure 8 is included to provide an easy comparison of observed values of $R(t)$ for cycle 24, as they become available, against that of the mean cycle (the bold line, representing the mean of cycles 10–23) for the first 6 yr of the sunspot cycle. The two thin lines above and below the mean line represents the ±1 *se* envelope. Also shown in figure 8 are the relative sizes of cycles 10–23 (*RM* values) and corresponding dates of maximum amplitude relative to the start of each cycle (*EM*, for epoch of maximum amplitude) and the relative sizes of their minimum amplitudes (*Rm* values) at onset. In figure 8, the asterisk denotes those cycles of shorter period, where the question mark for cycle 23 merely means its period is as yet unknown. Noticeable is that larger amplitude cycles tend to be cycles of faster rise than smaller amplitude cycles (the Waldmeier effect[1,14]) and often are of shorter period.

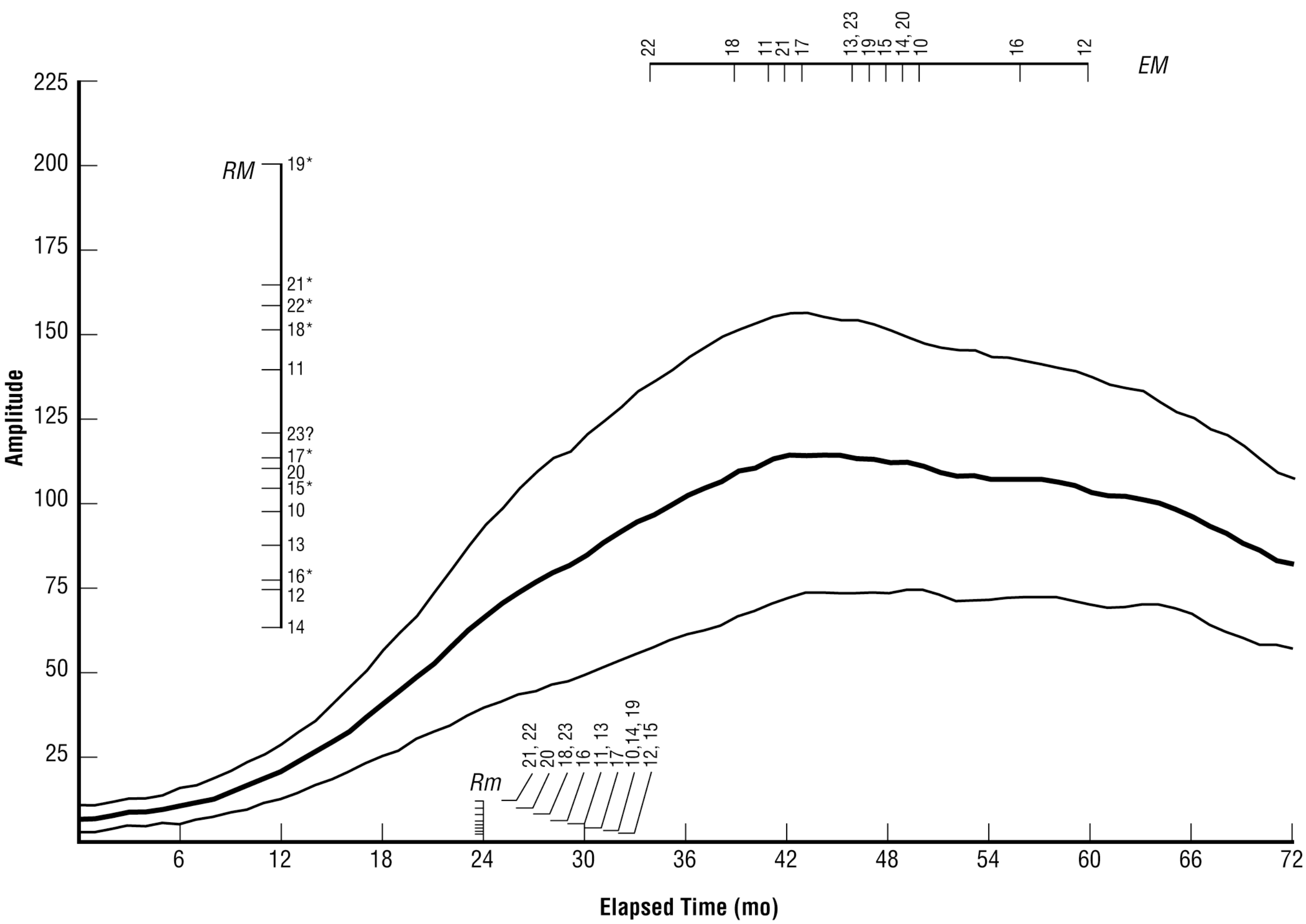

Figure 8. Mean cycle (10–23) from cycle minimum t equals 0 to 72 mo past minimum. See text for details.

3. CONCLUSION

In this brief study, it has been shown that throughout its rise, cycle 23, the present ongoing sunspot cycle, likely would have a maximum amplitude that would not differ appreciably from that of the mean cycle, a finding in contrast to what had been predicted for it on the basis of precursor information.[2,3] Hence, the maximum amplitude-early rise correlation has proven useful for accurately monitoring the projected maximum amplitude of an ongoing cycle. Likewise, because its average slope during the rising portion of the cycle measured 2.4, it appears highly likely that cycle 23 will be of shorter length, indicating that cycle 24's onset will occur sometime in 2006. Anticipating onset for cycle 24 within the next 2 to 3 yr, the maximum amplitude-early rise correlation has been updated to include cycle 23's behavior, and a chart has been prepared allowing individuals to easily plot its unfolding, comparing against that of the mean cycle and all modern era cycles (10–23).

REFERENCES

1. Wilson, R.M.; Hathaway, D.H.; and Reichmann, E.J.: "On Determining the Rise, Size, and Duration Classes of a Sunspot Cycle," *NASA TP–3652*, Marshall Space Flight Center, AL, September 1996.

2. Wilson, R.M.; Hathaway, D.H.; and Reichmann, E.J.: Prelude to Cycle 23: The Case for a Fast-Rising, Large Amplitude Cycle," *NASA TP–3654*, Marshall Space Flight Center, AL, October 1996.

3. Joselyn, J.; Anderson, J.; Coffey, H.; et al.: "Panel Achieves Consensus Prediction of Solar Cycle 23," *Eos Trans. AGU*, Vol. 78, p. 205, 1997.

4. Hathaway, D.H.; Wilson, R.M.; and Reichmann, E.J.: "A Survey and Synthesis of Solar Cycle Prediction Techniques," *J. Geophys. Res.*, Vol. 104, No. A10, p. 22,375, 1999.

5. Wilson, R.M.; Hathaway, D.H.; and Reichmann, E.J.: "Estimating the Size and Timing of Maximum Amplitude for Cycle 23 from Its Early Cycle Behavior," *J. Geophys. Res.*, Vol. 103, No. A8, p. 17,411, 1998.

6. Hathaway, D.H.; Wilson, R.M.; and Reichmann, E.J.: "Status of Cycle 23 Forecasts," P. Song, H.J. Singer, and G.I. Siscoe (eds.), *Space Weather, Geophys. Monogr. Ser.*, Vol. 125, p. 195, 2001.

7. Wilson, R.M.; and Hathaway, D.H.: "Gauging the Nearness and Size of Cycle Maximum," *NASA/TP—2003–21927*, Marshall Space Flight Center, AL, November 2003.

8. Wilson, R.M.; Hathaway, D.H.; and Reichmann, E.J.: "On the Correlation Between Maximum Amplitude and Smoothed Monthly Mean Sunspot Number During the Rise of the Cycle (from t = 0–48 months)," *NASA/TP—1998–208591*, Marshall Space Flight Center, AL, August 1998.

9. Wilson, R.M.: "On the Distribution of Sunspot Cycle Periods," *J. Geophys. Res.*, Vol. 92, No. A9, p. 10,101, 1987.

10. Wilson, R.M.; Hathaway, D.H.; and Reichmann, E.J.: "On the Behavior of the Sunspot Cycle near Minimum," *J. Geophys. Res.*, Vol. 101, No. A9, p. 19,967, 1996.

11. Everitt, B.S.: *The Analysis of Contingency Tables*, John Wiley & Sons, New York, pp. 15–20, 1977.

12. Hathaway, D.H.; Nandy, D.; Wilson, R.M.; and Reichmann, E.J.: "Evidence that a Deep Meridional Flow Sets the Sunspot Cycle Period," *Astrophys. J.*, Vol. 589, p. 665, 2003.

13. Hathaway, D.H.; Nandy, D.; Wilson, R.M.; and Reichmann, E.J.: "Erratum: 'Evidence that a Deep Meridional Flow Sets the Sunspot Cycle Period' (ApJ, 589, 665 [2003])," *Astrophys. J.*, Vol. 602, p. 543, 2004.

14. Wilson, R.M.; Hathaway, D.H.; and Reichmann, E.J.: "On the Importance of Cycle Minimum in Sunspot Cycle Prediction," *NASA TP–3648*, Marshall Space Flight Center, AL, August 1996.

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13. ABSTRACT *(Maximum 200 words)*

On the basis of the maximum amplitude-early rise correlation, cycle 23 could have been predicted to be about the size of the mean cycle as early as 12 mo following cycle minimum. Indeed, estimates for the size of cycle 23 throughout its rise consistently suggested a maximum amplitude that would not differ appreciably from the mean cycle, contrary to predictions based on precursor information. Because cycle 23's average slope during the rising portion of the solar cycle measured 2.4, computed as the difference between the conventional maximum (120.8) and minimum (8) amplitudes divided by the ascent duration in months (47), statistically speaking, it should be a cycle of shorter period. Hence, conventional sunspot minimum for cycle 24 should occur before December 2006, probably near July 2006 (±4 mo). However, if cycle 23 proves to be a statistical outlier, then conventional sunspot minimum for cycle 24 would be delayed until after July 2007, probably near December 2007 (±4 mo). In anticipation of cycle 24, a chart and table are provided for easy monitoring of the nearness and size of its maximum amplitude once onset has occurred (with respect to the mean cycle and using the updated maximum amplitude-early rise relationship).

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